PLAN FOR VERIFICATION OF FORECASTS IN THE NATIONAL DIGITAL FORECAST DATABASE

VISION: All sensible weather elements in the National Digital Forecast Database (NDFD) are verified by a suite of informative, scientifically sound performance measures and scores that are accessible by forecasters, managers, and users.

MANAGEMENT SUMMARY

Greg Mandt, Director Office of Climate, Water, and Weather Services, and Jack Hayes, Director Office of Science and Technology, created in June 2002 an Integrated Work Team (IWT) for National Verification of Gridded Forecasts. The IWT prepared this Plan; it is both high level and ambitious.

Of prime importance is the recommendation to create a National Verification Committee (NVC) reporting to the NWS Director. As such, it would essentially rejuvenate the NVC created in 1982, but has fallen into disuse the past decade. This team would work with the National Verification Program Manager to oversee all verification activities in the NWS to assure broad scope and organizational representation and to assure NDFD verification is appropriately integrated with other NWS verification activities.

The Plan identifies 21 tasks with estimated resources and suggested task leads. The tasks are not in priority order, but are roughly ordered in what can be done or started relatively soon. While the Plan was being developed, a prototype NDFD verification system was under development and is providing some information until a more complete and robust system is developed.

The NVC should be constituted immediately, and its first tasks should be to prioritize the verification tasks within the NWS, to develop an implementation plan for NDFD verification, and to secure necessary funds for a meaningful verification program. Forecast verification has not had adequate attention within the NWS, and the NDFD, being an entirely new way of making and providing forecasts, cannot be adequately dealt with within the resources currently allocated to verification.

Briefly, the Plan calls for the establishment of databases of official NDFD forecasts, forecast guidance, climatologies (relevant to verification), observations (relevant to verification), and forecast performance measures, and the tools to accomplish the establishment of those databases. It also encompasses the tools for producing the forecast quality metrics, quick forecaster feedback, training for managers and forecasters in use of verification metrics, and security.

1. Introduction

The National Digital Forecast Database (NDFD) is being implemented by the National Weather Service (NWS) in conjunction with the Interactive Forecast Preparation System (IFPS). Using IFPS, forecasters at Weather Forecast Offices (WFO) prepare forecasts on grids which are used to automatically prepare current textual products; these grids will also form the basis for an extended set of products. The grids are transmitted to a central server--the NDFD server--and mosaicked into "national" grids. National grids exist for the conterminous United States as well as for the Alaska Region and the Pacific Region.

The NDFD ushers in a new era in NWS service to customers and partners. The mosaicked grids will be available to all who desire to access them, and in addition certain graphical products will be produced from them. Private entities will be able to use the grids to produce a multitude of "value added" products. WFO forecasters, NWS managers, and customers need to know the quality of the gridded forecasts.

This plan specifically addresses verification of forecasts in the NDFD and does not encompass all of the verification that is carried out within the NWS. Because the NDFD grids are mosaics of individual WFO grids, the plan extends to the verification needed for individual grids at the WFOs.

Understanding what is meant by "verification" in this context is important. The following three definitions are extracted from the literature. The sense of the definition of verification has not changed over the span of 50 years.

- "Verification is usually understood to mean the entire process of comparing the predicted weather with the actual weather, utilizing the data so obtained to produce one or more indices or scores and then interpreting these scores by comparing them with some standard depending upon the purpose to be served by the verification." (Brier and Allen 1950)

- "Forecast verification--Any process for determining the accuracy of a weather forecast by comparing the predicted weather with the observed weather of the forecast period. Principal purposes of forecast verification are to test forecasting skill and methods." (American Meteorological Society 2000)

- "Forecast verification is the process and practice of determining the quality of forecasts, and it represents an essential component of any scientific forecasting system. As such, forecast verification serves many important purposes. These purposes include assessing the state of the art of forecasting procedures and ultimately the forecasts themselves, and providing users with information needed to make effective use of the forecasts." (Murphy and Winkler 1987).

Verification information is typically used for three purposes:

- to *monitor* the quality of the forecasts
- to *improve* the quality of the forecasts
- to *compare* the quality of two or more (possibly competing) forecast methods

The first purpose of verification is a requirement for every constituent involved in the forecasting process; forecasters and users need to know how well the forecasts are performing, and management requires long-term statistics for decision making. The second purpose mainly benefits the forecaster, one must first determine the situations and aspects of the forecasts that are incorrect before finding ways of improving future forecasts. The third purpose is a cross-cutting requirement of several constituent groups--forecasters can learn of the relative advantages and weaknesses of different types of numerical guidance, developers of numerical guidance can determine which experimental techniques will result in improved guidance, etc.

The NDFD is a collection of "official" NWS forecasts (as opposed to guidance). Initially, and what is explicitly addressed in this plan, the forecasts consist of grids of sensible weather elements. These weather elements are those needed to produce a current suite of text products and will be necessary to produce future graphic, text, and voiced products. The initial set of weather forecasts includes:

Daytime Maximum Temperature
Nighttime Minimum Temperature
Probability Of Precipitation (PoP)
Precipitation Amount
Temperature
Dew Point
Wind
Weather
Sky Cover
Snowfall
Wave Height

Grids of these elements are produced at WFOs at a grid spacing of 5 km or finer; temporal resolution varies by forecast projection, but is generally 3 hours through Day 3 and every 6 hours afterward. The grids are transmitted to the central NDFD server where they are mosaicked into national grids. Appendix A of NWSI 10-506 lists and defines each of the NDFD weather elements.

In the future, the NDFD will contain watches and warnings, but will not be the official means of disseminating these time critical products. It will also contain a third spatial dimension to support aviation needs, and other forms of data (e.g., objects) will be accommodated. This plan explicitly addresses forecasts on grids, but can be extended to other elements and dimensions as they become known.

Verification of forecasts residing on grids can be done by directly comparing observations with forecasts at observation locations for which "interpolated" values are obtained from the grids--so-called "point" verification. Alternately, the forecasts at the gridpoints can be compared directly with an analysis of observations where "verifying" values at gridpoint locations are obtained by some form of interpolation, which could involve a sophisticated data assimilation technique--so-called "gridded" verification. Another method involves verifying the characteristics of specific meteorological phenomena, for example, the central pressure of hurricanes or the location of a sea-breeze front--so-called "object" verification. In this method, meteorological "objects" are located and identified, possibly through the use of image processing and classification techniques, and the characteristics of the forecast objects are compared to those of the observed objects.

There are positive and negative aspects of each method. Issues related to spatial scale are of particular concern, especially when high-resolution grids are involved. The NDFD grids are at a grid-spacing of 5 km or less--much higher density than that of observations typically available in most areas. Because of the fine grid-spacing of NDFD forecasts, interpolation to an observation location will likely retain most of the information of the forecasts except in cases where the forecast contains significant small-scale detail, such as in very rough terrain. Having an observation available for verification is appealing, even with some error in measurement, and results can be compared directly with existing verification results [e.g., the so-called Public/Aviation system in use for over 20 years defined in the National Verification Plan (1982)]. However, in doing so, allowance must be made for the differences in the systems (e.g., NDFD forecasts interpolated to points vs forecasts made for the specific points being verified). Since information on the quality of the forecasts in regions where observations are not available cannot be obtained via the point verification method, some form of gridded verification is desirable. Such verification allows pattern-matching methods of verification. However, "gridded" verification depends on the quality of the analysis of the observed data. In addition, "object" verification results are sensitive to the methods used for identifying objects within the forecast and observed data. There is no single perfect verification method; therefore the NDFD verification system will contain a suite of verification techniques that include all three of the methods mentioned above.

This plan addresses the verification of forecasts residing on grids. It focuses primarily on several key areas: establishing a National Verification Committee, establishing databases suitable for verifying NDFD forecasts, development of verification tools, and providing verification measures to users and NWS personnel at all levels.

2. Operational concepts

From the outset, the NDFD verification system will reflect modern verification science and utilize state-of-the-art sensible weather analysis technology. The system will support grid-to-observation, grid-to-grid, and object-oriented verification, capabilities that will expand with the availability of new datasets and/or advances in data analysis techniques.

The NDFD verification toolbox will contain many different metrics and scores that can be computed at individual observational locations and gridpoints, mapped over arrays of these locations/points, or computed as aggregates over these arrays. The toolbox will enable the same scores to be computed in the same way at all NWS echelons (national, local, etc.). Forecasts have been categorized in many different ways; the following definitions will be used here. A *definitive* forecast is a single value of the forecasted (meteorological) variable. A *probabilistic* forecast is composed of a probability distribution for all possible values of the variable. In the case of a single event (e.g., precipitation), the forecast would consist of a single number. Forecasts can also be *continuous*, meaning any value can be predicted, or *categorical*, where categories representing specific ranges of values are predicted. Continuous forecasts can be converted into categorical through applying thresholds (such as maximum temperature greater than or equal to 50.0 and less than 60.0 degrees).

Gridded forecasts can be considered a set of individual forecasts at *gridpoints*, segmented into a set of meteorological *objects*, or treated as single entity *maps*. Appropriate verification measures depend on the type of variable being verified. NDFD variables generally fall into three types: *Continuous definitive forecasts* (i.e., daytime maximum temperature), *categorical definitive forecasts* (weather types), and *continuous probabilistic forecasts* (like probability of precipitation). Appendix A of NWSI 10-506 lists and defines each of the NDFD weather elements. In addition, Appendix I of this Plan lists the weather elements for which requirements exist for gridded forecasts and their verification.

A variety of verification methods can be used for these different types of forecasts. Each method provides information on various *aspects* of forecast performance. When analyzing results from a particular verification method, it is important to understand what aspects of forecast performance the information is revealing. A complete analysis of the forecast verification information is provided by the *joint distribution* of forecasts and observations, analysis of which is known as the *distributions-oriented* approach to verification (Murphy and

Winkler 1987). Within the distributions-oriented approach, Murphy (1993) defines several specific aspects of forecast quality. These include *bias, accuracy, association, skill, reliability, resolution, sharpness, discrimination*, and *uncertainty*. The NDFD verification system will have the capability to provide information on all of these aspects of forecast quality.

Categorical forecasts naturally lend themselves to a distributions-oriented verification approach that is more informative than one emphasizing the use of summary measures. In this approach, potentially useful information is extracted from factorizations (emphasizing conditional and marginal probabilities) of the joint distribution of the forecasts and observations.

The NDFD verification system will provide contingency tables for specified forecast/observation sets either routinely or by demand from which a variety of distributions-oriented or summary measures can be computed. A distributions-oriented analysis can also be usefully applied to continuous predictands after the forecasts and observations have been categorized. This capability will also be built into the NDFD verification system.

The NDFD verification system will support multiple functions. These include providing (1) feedback through 'daily forecast critiques' to the operational forecasters who produce the gridded products, (2) diagnostics to those who develop or maintain guidance for the forecasts, (3) performance characteristics of both the forecasts and the guidance to forecasters and to end or intermediate customers, and (4) summary information to NWS managers at all levels. To achieve this capability, the system has to be accessible, flexible, and efficient. Users must have the ability to *stratify* verification data samples by season, time of day, weather regime, or other related conditions.

A web-based system is envisioned that routinely produces a standard suite of verification information cross-cutting as many user requirements as possible, and can also be used interactively via AWIPS by a forecaster for his/her daily critique or an analyst/user to custom tailor verifications (with user-defined scores, thresholds, domains, time periods, or forecast sets). The latter capability implies access to a rich verification toolbox and all of the sources of data (forecast, guidance, observations, analysis, climate) supporting the system. This in turn implies the need for modular design, relational database management, and rapid communications.

System capabilities will be developed, phased in, and upgraded over time. The NDFD verification system requires an open and clear process for implementation of updates. These advances will include verification techniques, new and improved observational data, data access and visualization procedures, etc., that will be obtained from sources within the NWS and from the academic and research communities. Comprehensive training will be made available to forecasters and managers, and educational material will be made available to external users via the web to allow for optimal use of the verification information. Finally, the system will enforce good practices for custom-tailored verification by alerting the user to inappropriate stratifications (e.g. sample sizes too small and/or error bars too large), inhomogeneous comparisons (different sets of forecasts), or potential misinterpretation of particular statistics (e.g. correlation has no information about bias or amplitude errors).

3. National Verification Committee

It is critical a central body be established to oversee the verification activities of the NWS. An NVC was established in 1982 by the Director of the NWS. It met regularly for nearly a decade, and under its auspices the *National Verification Plan* (1982) was implemented. However, the committee has not met for over 10 years, and an NWS wide committee is needed to foster a broad view of verification and assure adequate field participation.

This Plan addresses only verification of NDFD forecasts. However, all aspects of verification must be addressed by the NVC and not just NDFD forecasts in isolation. The NVC must have membership from all NWS Headquarters Offices and each NWS Region and NCEP. The responsibilities of the NVC must include recommending budgets for verification, allocation of resources, and priorities for development and operations. Collaboration and peer review must be sought from academia, private enterprise, and government organizations outside the NWS, as appropriate.

The NWS Verification Program Manager working with the National Verification Committee (NVC) would ensure execution of this Plan. On a regular basis he will report to the NVC and the NWS Corporate Board on progress made toward milestone completion, highlight any potential issues that may prevent the milestone being attained, and, if appropriate, propose corrective action.

4. Actions and tasks

Each task identified in this plan will be assigned to an NWS organization which will appoint a verification focal point who will monitor respective office responsibilities and coordinate as necessary with other NWS staff offices and field counterparts to ensure the accomplishment of all action items within the office’s area of responsibility. The focal point for an office may be the office's member on the NVC. Focal Points will provide progress reports to the Program Manager on a schedule mutually agreeable when actions are assigned and accepted.

Specific actions and tasks are listed below. A lead organization is suggested, but the lead will be determined by the NWS Program Manager in concurrence with the NVC. In all cases, the lead organization will coordinate with all appropriate organizations, including The National Climatic Data Center (NCDC), the National Center for Atmospheric Research (NCAR), the Forecast Systems Laboratory (FSL), and academia. A schedule (suggested time line) for these activities is given in Appendix II.

4.1 Prepare NDFD Verification Implementation Plan.

A critical task for the NVC is to prepare an Plan to implement this aggressive Verification Plan and to coordinate the activities with other NWS verification efforts. The NDFD Verification Plan is very aggressive, and the NVC must quickly assign priorities and secure funding for the most critical and achievable tasks.

Time frame:	Jan. 1 - March 31, 2004
Tasked to:	NVC/OCWWS
Cost:	In house resources

4.2 Implement and maintain the MDL prototype NDFD verification system as the initial operational verification system.

This web-based system, which can be linked to the existing OCWWS web site, will provide global access to monthly performance statistics using grid-to-point and grid-to-grid methods for several, but not all, NDFD weather elements. This verification system is but the initial version, and many improvements and upgrades will be implemented in the near term. However, this initial verification system will meet the requirement of having a system in place to verify the operational NDFD products. Appendix III details the capabilities of this initial system.

Time frame:	Implement immediately and maintain until a more complete system is in place
Tasked to:	OST/MDL
Cost:	MDL in-house resources

4.3 Archive operational NDFD forecasts, related numerical guidance, and observations.

As forecasts in the NDFD become "official," they will immediately begin to be archived, along with NDFD-related forecasts, raw and post-processed numerical guidance, and observations of weather elements for the purpose of eventually populating a long-term verification database. OST/MDL will work with NCEP/EMC to obtain NDFD-related numerical guidance on the appropriate NDFD grid in GRIB2 format. Once a relational database management system (RDBMS) for NDFD verification has been established (see Task 4.4), that database can be populated on the NDFD grid with the operational NDFD forecasts, numerical guidance, and associated observations so that verification statistics for the archived forecasts can be obtained.

Time frame:	Jan 1, 2004 and maintain until a more complete system is in place and data are transferred to the RDBMS
Tasked to:	OST/MDL
Cost:	$220K/yr (2.0 Contractors) $50K/yr Hardware (server/storage)

4.4 Acquire relational database management software.

A RDBMS with geographical information system (GIS) capabilities will be required in order to satisfy the requirements of flexibility and modular design for the NDFD verification system. Implementation of this system is of first priority, since it will be the foundation of the NDFD verification system that is envisioned by this plan. Database management experts should be consulted to select a RDBMS that will meet the current and future requirements of the verification system. Security of the data as well as internet access must be ensured. The RDBMS must be capable of serving a user-defined subset of forecast, guidance, control, and/or observed data, in the form of raw data (in WMO standard formats), images, tabular, or summary verification statistics.

Time frame:	Jan. 1, 2004-June 30, 2004
Suggested Lead:	OST/MDL and OST/SEC
Cost:	$50K for licenses and support.

4.5 Establish NDFD verification database.

Once the RDBMS has been acquired, the data models for the NDFD forecasts, observations, numerical guidance, analyses of observed weather elements, climatology, and other components of the verification database must quickly be defined. Pertinent metadata must be included, such as issuance time and date, forecast projection, location (latitude and longitude, forecast office, region), instrument type, source of information (analysis type, model name, type of control), data format, etc. The metadata must cover necessary attributes of forecast and observed data such that any user of the verification database can define a desired subset of forecast and observed data (by date, time, office, region, etc.), define the type of verification, and compute and execute the verification request.

Time frame:	July 1, 2004 - September 30, 2004
Suggested Lead:	OST/MDL
Cost:	$40K (1.5 Contractors)

4.6 Populate verification database with NDFD forecasts.

The verification database will be populated with gridded NDFD forecasts to allow for on-demand calculation of verification statistics. The verification database will serve up a customizable subset of NDFD forecasts to compare against observed conditions. The NDFD forecasts should be placed in the verification database in near real-time. Archived NDFD forecasts beginning with the first official grids will be placed in the verification database (see Task 4.3).

Time frame: Oct. 1, 2004 - Continuing
Suggested Lead: OST/MDL
Cost: $55K/yr. (0.5 Contractor)

4.7 Populate verification database with NDFD-related numerical guidance and interpretative forecasts.

The verification database will be populated with numerical guidance (MOS, Eta, GFS, etc.) of weather elements that are represented on the operational NDFD grid to allow for on-demand calculation of verification statistics. The verification database will serve up a customizable subset of NDFD-related guidance forecasts to compare against observed conditions. The numerical guidance products should be placed in the verification database in near real-time. Archived numerical guidance will match dates of the official grids (see Task 4.6).

Time frame: Oct. 1, 2004 - Continuing
Suggested Lead: OST/MDL
Cost: $110K/yr. (1.0 Contractor)

4.8 Populate verification database with NDFD-related ASOS and other observations of weather elements.

The verification database will be populated with observations [e.g., ASOS, buoy, and Coastal Marine Automated Network (C-MAN)] to allow for on-demand calculation of verification statistics when using the grid-to-point method. The verification database will serve up a customizable subset of observations to compare against NDFD and numerical guidance. The observations should be placed in the verification database in near real-time. Archived observations will match dates of the official grids (see Task 4.6).

Time frame: Oct. 1, 2004 - Continuing
Suggested Lead: OST/MDL and OCWWS/Observing Services
Cost: $110K/yr. (1.0 Contractor)

4.9 Populate verification database with modern, high-density data from observation networks such as mesonets and modernized cooperative observations.

Other NWS and non-NWS data sources with reliable instrumentation and proper sensor exposures will be added to the verification database as appropriate.

Time frame: Oct. 1, 2004 - Continuing
Suggested Lead: OST/MDL and OCWWS/Observing Services
Cost: $220K/yr (2.0 Contractors)

4.10 Establish quality control procedures for observations in NDFD verification database.

Influx of high-density data from observational networks from both inside and outside of NWS will require automated quality control procedures to ensure high-quality verification information. Much of this quality control will be a requirement of the modernized COOP network and the concept of a National Mesonet. However, the verification program will need to monitor and assure this quality control is appropriate for the data ingested into the database. These requirements will expand as the weather elements in the NDFD expand to include aviation forecasts, etc.

Time frame: Jan. 1, 2005 - Continuing
Suggested Lead: OST/MDL/PPD and OCWWS/Observing Services
Cost: $55K/yr. (0.5 Contractor)

4.11 Develop data assimilation system to provide realistic gridded analyses to be included in the NDFD verification database.

To ensure the validity of the grid-to-grid and object-oriented verification methods, an analysis of NDFD weather elements, called the *"analysis of record"* must be developed, which will contain a realistic representation of the small-scale variability that can be resolved by the NDFD grid. This work should be leveraged within the mesoscale data assimilation development that NCEP/EMC must do in order to provide initial conditions for high-resolution numerical weather prediction models. However, this analysis should be independent of the current NWP analyses schemes. Work should be conducted collaboratively with extramural researchers including academia and other NOAA laboratories. The data assimilation system must include all available observation sources (radar, satellite, GPS, aircraft, ASOS, mesonets, COOP modernization, etc.) and a sophisticated weather prediction model that is capable of resolving the small-scale variability that can be represented by the NDFD grid. Scale-recursive estimation methods (Tustison et al 2002) should be explored to ensure that the natural variability of the weather elements is maintained, given the range of spatial scales that can be observed by the various observational data platforms.

Time frame: January 1, 2004 - Continuing
Suggested Lead: NCEP/EMC
Cost: $330K/yr. (3.0 Contractors for 2 years)
$110K/yr. (1.0 Contractor after 2 years)

4.12 Put gridded analyses of NDFD weather elements into verification database.

The verification database will be populated with analyses of NDFD weather elements that are represented on the operational NDFD grid to allow for on-demand calculation of verification statistics. Operational analyses (e.g., RUC, EDAS, GDAS, LAMP, Radar Stage IV) will be obtained from NCEP on the NDFD grid in GRIB2 format. Once the analysis of record (see 4.11) is available, it will be used as the primary reference. The verification database will serve up a customizable subset of NDFD-related analyses to compare with gridded forecasts to serve the grid-to-grid and object-oriented verification methods. The analysis products should be placed in the verification database in near real-time. Analysis fields should be inspected (via Fourier power spectra, structure function, etc.) to determine the smallest spatial scales that are resolved in each analysis. For each source of analyzed observed data, verification statistics should be computed only at resolved spatial scales and larger. This will require smoothing/subsampling of the forecast data in order to match the resolved vertical and horizontal scales contained in each analysis.

Time frame: Oct. 1, 2004 - Continuing
Suggested Lead: OST/MDL
Cost: $110K/yr. (1.0 Contractor)

4.13 Develop climatology of weather elements on NDFD grids.

Many verification skill scores require a comparison to the accuracy of climatology. A climatology of NDFD weather elements that contains a realistic representation of the small-scale variability that can be resolved by the NDFD grid must be developed. This work should be tasked to NCDC but should leverage the mesoscale data assimilation/reanalysis development at NCEP/EMC and other efforts. Ultimately, the techniques to produce the climatology should match those used in producing the analysis of record (see 4.11) and include both the mean and variance. In the meantime, application of downscaling techniques, which provide means of including realistic small-scale structure given coarser-scale estimates of weather elements (e.g., Perica and Foufoula-Georgiou 1996; Harris et al 2001; Tustison et al 2002; Zepeda-Arce et al 2000), to 32km Eta regional reanalysis data should be explored. Work being done at NCEP/CPC should be leveraged.

Time frame: January 1, 2004 to December 31, 2006
Suggested Lead: OST/PPD
Cost: $110K/yr (1.0 Contractor)

4.14 Implement verification tools within RDBMS.

A suite of performance measures will be available for calculation using the verification database. These tools will be available globally via web access as well as locally at forecast offices via database management programs. At a minimum, the verification tools will provide score-specific event/regime stratification capabilities matching those specified in TSP89-11 (NWS 1989), with specific default thresholds to be defined by OCWWS. The NDFD verification system will provide the capability to generate and display images of products contained within the verification database (forecasts, observations, guidance, analyses, controls) to allow for visual verification. The NDFD verification system will provide the capability to generate and display contingency tables, raw joint distributions, and the calibration-refinement or likelihood-base rate factorizations. The NDFD verification system will provide the capability to generate and display scatter plots of continuous observed and forecast values. A variety of standard measures of bias, accuracy, reliability, sharpness, resolution, discrimination, and skill will be available for computation in NDFD verification. The verification system will include the capability of measuring the multi-scale statistical properties of grids and time-series of weather elements in order to verify the structure and variability of the forecast elements. The uncertainty of verification scores will be estimated using analytical and bootstrapping techniques. This will require a suite of mathematical tools for statistical analysis, time signal and image processing, data mining, and wavelet analysis. Object-oriented verification tools will also be made available. The development of verification tools will be an ongoing process, with capabilities added over time. The process for updating and including new verification tools will be made clear and open.

Time frame: July 1, 2004 - Continuing
Suggested Lead: OST/MDL
Cost: $330K/yr. (3.0 Contractors)

4.15 Promote research and development of new verification tools.

Research into modern gridded and object-oriented verification techniques is in the infant stages. In order to obtain the type of meaningful verification information envisioned by this plan, the NWS must partner with academia and researchers from other Government agencies in the field of verification.

Time frame: July 1, 2004 - continuing
Suggested Lead: OST/Program and Plans Division

Cost: $150K/yr. (Contract)

4.16 Develop AWIPS/D2D and web access capability for verification database.

Users will be able to access the full suite of verification tools, NDFD forecasts, observations, guidance, and controls that are included within the NDFD verification database. The verification database will serve up a customizable subset of NDFD-related products that will allow visual, grid-to-point, grid-to-grid, and object-oriented verification methods. The database will be capable of serving original products (NDFD, guidance, observations, analyses) in international (WMO) standard formats [GRIB2, BUFR (WMO 2001)]. The amount of data that can be served from the database via the web must be limited to ensure quick access to global users; off-line access to the long-term verification database archive can be offered via external media. Prototype web access systems to verification databases can be found in OCWWS's Verification/Storm Data Web Site, FSL's Real Time Verification System (RTVS), MDL's NDFD, MOS, and AVP verification, and HPC's National Precipitation Verification Unit (NPVU). Web access must allow a user to define the type of verification method to use, the subset of forecast and observed data to collect, and contain training and educational material to help the user interpret the verification information.

Time frame: Jan. 1, 2004 - Continuing, Initial capability by Dec. 31, 2004.
Suggested Lead: OST/MDL and OCWWS/Performance and Awareness
Cost: $110K/contractor/yr. (Contractor profile by year: 2, 4, 4, 3, 2)

4.17 Develop training material for NDFD verification.

Training sessions on verification methods, application of results, and use of the NDFD verification system will be provided to forecasters, managers, partners, and customers. Modules will be developed in consultation with experts in the field of verification and trainers such as those at COMET and the NWS Training Center. Development of specific educational resources will evolve with the NDFD verification system. All modules will be prepared for delivery via distant learning procedures. Pertinent training will be accomplished via various forms of distance learning near the time of implementation of new verification tools and procedures for accessing the database. A substantial portion of verification training can be integrated into IFPS/NDFD training.

Time frame: Jan. 1, 2004 - Continuing, initial modules by June 30, 2004.
Suggested Lead: OCWWS/Performance Branch, and OCWWS/Training Division
Cost: $220K/yr. (2.0 Contractors)

4.18 Make locally-produced numerical guidance available to NDFD verification database.

Numerical models run locally at individual forecast offices will play a role in the forecast preparation process; therefore the quality of guidance provided by such models and their interpretation algorithms (e.g., SmartInit) must be measured. The local guidance can be verified along with the NDFD forecasts, national guidance, etc., against observations and analyses found within the NDFD verification database with NDFD verification tools.

Time frame: Jan. 1, 2005 - Continuing
Suggested Lead: OST/MDL
Cost: $110K/yr. (1.0 Contractor)

4.19 Archive NDFD verification database.

Once the verification database is implemented, a long-term archive of the database must be established and maintained. The archive will contain the data, verification tools (NDFD-related forecasts, numerical guidance, and observations) contained within the database. A process to allow external users to obtain subsets of the archive via digital media and/or ftp must be established. The long-term archive should be located and maintained at NCDC.

Time frame: June 30, 2005 - Continuing
Suggested Lead: OST/MDL
Cost: 110K/yr. (1.0 Contractor)

4.20 Archive NDFD verification performance measures and scores.

Once the verification database is implemented, a long-term archive of the performance measures and scores must be established and maintained. A process to allow external users to obtain requested measures and scores must be established. The long-term archive should be located and maintained at NCDC.

Time frame: June 30, 2005 - Continuing
Suggested Lead: OST/MDL
Cost: 110K/yr. (1.0 Contractor)

4.21 Insure that the databases created are secure and FOIA-exempt.

This activity cuts across many other tasks, but is of sufficient importance to include as a separate focus.

Time frame: Jan. 1, 2004 - Continuing
Suggested Lead: CIO
Cost: In House Resources for Consulting

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APPENDIX I

Weather Elements of Verify

The following is representative of weather elements to verify. The list is not necessarily complete, and other elements would be dealt with as they become known; however, there currently exists requirements for gridded forecasts of these elements. While not in priority order, the first dozen are generally those that have been verified in the past and tend to be more universal and better defined.

Max/Min Temp (general weather element): The daytime max or overnight min temperature. Verifying observations are deduced via a comprehensive algorithm that examines reported max/min and hourly temperatures. Daytime is defined as **0700-1900 Local Standard Time**, and **1900-0800 Local Standard Time**. The 1 hour overlap was introduced by the NWS in the mid 1980s to include mins that occur just after sunrise.

Temperature (general weather element): A snapshot of the expected temperature in degrees F valid at the indicated hour. Values in IFPS should be populated each hour in order to support both UTC sampling intervals for NDFD and LTC sampling intervals for local products.

Dewpoint (general weather element): A snapshot of the expected dew point temperature in degrees F valid at the indicated hour. Values in IFPS should be populated at each hour in order to support both UTC sampling intervals for NDFD and LTC sampling intervals for local products.

PoP12 (general weather element): The likelihood, expressed as a percent, of a measurable precipitation event (1/100th of an inch) at a gridpoint during the valid period. The 12-hour periods begin and end at 0000 and 1200 UTC. This can be different than the LTC-based PoPs placed in local products (e.g., ZFP). With IFPS 11, PoP12 values can be derived from floating PoP12 values.

Floating PoP12 (general weather element): A special value from which a PoP12 for any 12-hour period can be derived by taking the maximum floating PoP12 value within the desired period. A floating PoP12 should be thought of as that hour's contribution to the PoP12, not as a PoP01, which has different statistical characteristics. Floating PoP12 values are best stretches over time ranges consistent with other precipitation related elements, and that in the end result in complete coverage at every hour. Floating PoP12 grids support the generation of PoP12s in both UTC and LTC.

QPF (general weather element): The total amount of liquid precipitation (in hundredths of inches) at a gridpoint. Periods for the NDFD end and begin at 0600, 1200, 1800, and

0000 UTC. Periods for local products vary. In IFPS, QPF grids can be stretched to any length of time. Amounts for the NDFD and local products are calculated, as appropriated, from derived hourly accumulation rates.Snow Amt (general weather element): The total snowfall accumulation (in whole inches) at a gridpoint. Periods for the NDFD end and begin at 0600, 1200, 1800, and 0000 UTC. Periods for local products vary. In IFPS, Snow Amt grids can be stretched to any length of time. Amounts for the NDFD and local products are calculated, as appropriated, from derived hourly accumulation rates.

Wind Dir (general weather element): Snapshot of the expected wind direction forecast to occur during the indicated hour, using 36 points of a compass. Values in IFPS should be populated each hour in order to support both UTC sampling intervals for NDFD and LTC sampling intervals for local products.

Wind Spd (general weather element): Snapshot of the sustained wind speed (in knots) forecast to occur during the indicated hour. Wind speeds are converted to mph, as appropriate, by IFPS/NDFD product generation software. Values in IFPS should be populated each hour in order to support both UTC sampling intervals for NDFD and LTC sampling intervals for local products.

Wind Gusts (general weather element): Snapshot of the expected wind gust (greater than 10 kts over sustained), if any, forecast to occur during the indicated hour. Wind speeds are converted to mph, as appropriate, by IFPS/NDFD product generation software. Values in IFPS should be populated, when expected, each hour in order to support both UTC sampling intervals for NDFD and LTC sampling intervals for local products.

Sky Cover (general weather element): Snapshot of the expected amount of all clouds (in percent) covering the sky during the indicated hour. Values in IFPS should be populated at each hour in order to support both UTC sampling intervals for NDFD and LTC sampling intervals for local products.

Weather (general weather element): Snapshot of expected weather during the indicated hour. The element includes type, probability, and intensity information. In cases of convective weather, coverage may be substituted for probability. Values in IFPS should be populated at each hour in order to support both UTC sampling intervals for NDFD and LTC sampling intervals for local products. A weather grid should have a non-null value at any gridpoint with a corresponding with corresponding PoP12 value of at least 15 percent.

WWA Valid Time Event Codes (general weather element):

Heat Index (general weather element): Derived field.

Wind Chill (general weather element): Derived field.

Relative Humidity (general weather element): Derived field.

Max/Min Relative Humidity (fire weather element):

Free Air Wind (fire weather element): ie Ridgetop wind.

Lightning Activity Level (fire weather element):

Mixing Height or Stability (fire weather element):

Transport Wind (fire weather element):

Haines Index (fire weather element):

Temperature Trends (fire weather element): (24hour) (derived field)

Relative Humidity Trends (fire weather element): (24hour) (derived field)

Dispersion Index (fire weather element): ??

Fire Weather Watch VTECs (fire weather element):

Red Flag Warning VTECs (fire weather element):

Swell Height (marine weather element): Wind generated waves that have traveled out of their generating area, expressed as height (trough to crest) in feet.

Swell Direction (marine weather element): Swell Direction is the compass direction from which the swell waves are coming from.

Significant Wave Height (marine weather element): The average height (trough to crest) of the one-third highest waves.

Visibility (marine weather element): Maximum number of nautical miles an object can be seen and identified in the horizontal. The maximum distance is determined for a minimum area of one half of the horizon circle. Visibility grater than 6 nautical miles is unrestricted.

Marine Watch/Warning VTECs (marine weather element):

APPENDIX II

Proposed Schedule

The proposed schedule on the following two pages is ambitious; the estimated resources for each task are indicated. Some tasks can be started immediately, but many cannot be begun without significant commitment of resources.

APPENDIX III

Capabilities of Interim Verification System

I. Introduction

MDL has developed a prototype verification system (Dagostaro, et al. 2004) and has been providing statistics from it via a web page to management and forecasters for several months. This system contains both grid to point and point to point verification components. Display methods comprise raw statistics, plots of error statistics vs projection, and maps. The site is located at:

http://slosh.nws.noaa.gov

II. Overall Structure

NDFD forecasts are archived in a flat file structure; no use of an RDBMS is made. These forecasts are housed on the NCEP IBM mainframe.

Observations are also archived, as well as available analyses of weather elements of use in verifying NDFD forecasts.

III. Point to Point

The NDFD forecasts can be "interpolated" to observation points by one of three methods: 1) bilinear, 2) biquadratic, or 3) nearest neighbor. Generally, the nearest neighbor method is used with special treatment of coastal sites when the nearest NDFD gridpoint is over water. These NDFD forecasts can be compared to available observations and appropriate scores computed. On the web site, the scores are available on a monthly basis for individual observation sites, for WFO CWA, for NWS regions, and for the nation as a whole. Other user-defined aggregations of points and user-defined time periods are possible and can be requested of MDL.

The scores that can be computed by weather element are shown in the table below. An asterisk indicates the capability is not yet fully functional.

	MSE	Bias	Brier Score	Heidke Skill	Error Freq
12-Pop			x		
3-h Temperature	x	x			
3-h Dew Point	x	x			
Max/Min Temp	x	x			
3-h Wind Speed	x	x		x	
3-h Wind Dir	x	x		x	x
Cloud		x*		x*	

IV. Grid to Point

The NDFD forecasts can be compared gridpoint to gridpoint for any appropriate analysis available. For instance, the 20-km RUC analyses have been used and are shown on the web site. A locally-prepared analysis, such as that from the University of Utah, can be used. Essentially, any analysis can be used. At present, MDL can deal with GRIB and GRIB2 formats. The scores can be for individual gridpoints, or be aggregated over user defined areas (e.g., a WFO CWA or an NWS region).

The scores that can be computed by weather element are shown in the table below. Scores for other elements await an appropriate analysis.

	MSE	Bias	Brier Score	Heidke Skill	Error Freq
3-h Temperature	x	x			
3-h Dew Point	x	x			
3-h Wind Speed	x	x		x	
3-h Wind Dir	x	x		x	x